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# Microbial and some heavy metals analysis of smoked fishes sold in urban and rural markets in Akwa Ibom State, Nigeria

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## ABSTRACT

**Objective:** The unhygienic nature of our local markets, including fish handlers, may contribute to the presence of microorganisms in smoked fish leading to food poisoning. Furthermore, heavy metals can find their way into the food chain through fish raising public health concerns. This study assessed the microbial load and some heavy metals in smoked fishes (bongafish and catfish) sold in urban and rural markets in Akwa Ibom State, Nigeria.

**Materials and Methods:** Standard microbiological techniques and analytical procedures were used for microbial and heavy metals analyses, respectively.

**Results:** The results revealed that all the smoked fish obtained from the two markets were contaminated with heavy metals and microorganisms. Zinc was the most frequently detected heavy metal in both fish types (catfish: 15.50 ± 9.99 mg/kg; and bongafish: 16.40 ± 12.28 mg/kg) obtained from urban market, while in the rural market, it was cadmium (catfish: 15.95 ± 10.15 mg/kg; and bongafish: 18.25 ± 7.15 mg/kg). The overall elemental concentrations of the heavy metals in the fishes were in decreasing order of Cadmium>Zinc>Nickel>Cobalt>Lead. The most predominant bacterial species in fishes from the urban market was *Bacillus subtilis* ($7.5 \times 10^4 \pm 0.871$ colony-forming unit/g) while *Candida tropicalis* ($9.2 \times 10^4 \pm 0.105$) was the most predominant fungal species. More bacteria and fungi were encountered in fishes from the rural market than from the urban market. The differences in the microbial loads from the two markets were not statistically significant ($P > 0.05$).

**Conclusion:** There is a potential health risk of eating smoked fishes that are poorly stored or handled in the market as a result of heavy metal contamination and the presence of the pathogenic organism. Therefore, maintenance and enforcement of adequate sanitation practices in these markets should be encouraged to avert unpleasant health consequences.

**Keywords:** Smoked fish, Heavy metals, Microbial contamination, Health implications

## INTRODUCTION

Fish generally encompass all seafoods, including fined fishes, Crustaceans with chitinous exoskeleton such as Lobsters, Crabs, Shrimps, Muscle cockles, and oysters.[1] It is a high protein, low-fat food and an important source of essential nutrients required for supplementing both infants and adult diets and provides a range of health benefits.[2] In general, nearly 20% of animal protein sources are provided by fish[3] and it is a rich source of protein for the poor and wealthy.[4]

Fish contains most of the important essential amino acids, particularly, lysine, methionine, and tryptophan that are lacking in plant proteins.[5]

Fish has wider acceptability in most parts of Nigeria due to its unique taste, flavor, and good texture.[6] Species such as bongafish (*Ethmallosa fimbriata*) and catfish (*Clarias gariepinus*) is highly accepted and consumed in their smoke-dried form in Nigeria, particularly Akwa Ibom State due to their affordability and highly delicious flesh. Some natural and human activities have been a source of heavy metal pollution and microbial contamination in the aquatic environment. Aquatic organisms such as fish and shellfish accumulate metals in their different organs and tissues.[7] At low concentrations, some heavy metals such as copper, cobalt, zinc, iron, and manganese are essential for biological which when consumed can have potential health consequences.[8] Furthermore, poor conditions in our local markets, fish handlers, and fish smoking facilities may contribute to the presence of microorganisms in smoked fish. These have led to the persistence of food poisoning which is an alarming health problem of developing countries where sanitation is low.[6]

The aim of this study was to assess the microbial burden and heavy metal concentrations in local processed and stored smoked fish products sold in Akpanandem (urban) and Ifiayong (rural) markets in Akwa Ibom State of Nigeria and to highlight their public health implications.

## MATERIALS AND METHODS

### Sample source and collection

A total of 40 samples of smoked pieces of *C. gariepinus* (Catfish) and *E. fimbriata* (Bongafish) were purchased from Uruan (Ifiayong) and Uyo (Akpanandem) markets (20 from each market), all in Akwa Ibom State of Nigeria. The state is located in the Niger Delta region of Nigeria between the latitudes 4˚31 and 5˚53' North and longitudes 7˚25' and 8˚25' East. The fish marketers were selected by a simple random sampling method using the balloting technique. The samples were wrapped in new polyethylene bags, labeled properly, and transported to the University of Uyo Microbiology and Chemistry Laboratories for Microbiological and Chemical Analysis, respectively.

### Microbiological analysis

The fish samples were first crushed separately in a mortar and homogenized using an electric blender. For the microbiological analysis, 1.0 g of the crushed fish samples were homogenized in 9 ml of sterile water. A ten-fold serial dilution using physiological saline (Oxoid) was prepared (each from skin, intestine and gills of the fish as well as the viscera of the shrimp) and 1 ml of the desired dilution levels were plated in triplicates on appropriate media using the pour plate method.

Enumeration of bacteria and fungi was performed on appropriate media as follows: total heterotrophic bacteria on nutrient agar; total coliform bacteria on MacConkey; *Salmonella*/*Shigella* on *Salmonella*/*Shigella* agar; *Vibrio* on Thiosulfate Citrate Bile Salts sucrose; *Staphylococcus* on Mannitol salt agar; and fungi on Sabouraud Dextrose agar.[9] For fungal growth and suppression of bacterial growth, streptomycin and penicillin solution (50 μg/ml and 50 IU/ml, respectively) supplemented medium was used for the selective enumeration and isolation of fungi. The Petri plates inoculated for bacterial enumeration were incubated at 37°C in the Gallenkamp incubator for 24 h, while those for fungal enumeration were held at room temperature (25°C) for 7 days. Discrete colonies that appeared on the culture plates were enumerated with the aid of a Quebec Colony Counter and recorded as colony-forming unit (cfu/g). Bacterial isolates were identified by standard biochemical tests including Gram reaction, catalase, motility, coagulase, Methyl-Red Voges-Proskauer test, starch hydrolysis, citrate, urease, and sugar fermentation.[10] Fungi isolates were identified according to the methods of Domsch *et al*.[11] and Barnett and Hunter.[12]

### Heavy metal analysis

The homogenized fish samples were weighed (5 g) into a porcelain crucible. Before ashing, 1 ml of concentrated $HNO_3$ was added to the samples and allowed to pre-digest overnight to reduce losses of volatile metals. The samples were charred on an electric hot plate before ashing in a muffle furnace at 55°C for 24 h. The ash was dissolved in 5 ml of 1:1 HCL and a solution made in a 50 ml standard flask,[13] metal concentrations of the samples were read against appropriate blank standard solutions of Cd, Zn, Ni, Co, and Pb using a Perkin-Elmer Model 306 atomic absorption spectrometer according to the method described by Okoye.[13] A blank solution for the biotic samples was made by diluting 1 ml concentrated $HNO_3$ with 5 ml of 1:1 HCl and a 50 ml solution made up with distilled water and the individual metals expressed on a dry weight basis as mg/kg.

### Data analysis

Data obtained from the microbiological assay in the study were analyzed statistically using one-way analysis of variance to determine whether there were any significant differences between the means of independent groups. Differences among means were determined by the least significant difference, and 95% confidence level was used as an indication of statistical significance ($P \leq 0.05$). This was also the method for analyzing data generated from heavy metal concentration analysis. Student's *t*-test was used to compare

the degree of heavy metal and microbial contamination of fishes in Uyo and Uruan markets.

## RESULTS

The results of the heavy metals load of two types of smoked fishes; *C. gariepinus* (Catfish) and *E. fimbriata* (bongafish) from the urban market (Akpanandem market) and rural market (Ifiayong market) are presented in Tables 1 and 2, respectively. In catfish, zinc, and nickel had the highest heavy metal load with a mean load of 15.50 ± 9.99 mg/kg and 12.85 ± 9.45 mg/kg, respectively, while cadmium (19.55 ± 3.84 mg/kg) and zinc (16.40 ± 12.28 mg/kg) were the highest in bongafish. The concentration of lead was low among the heavy metals detected in both fishes with a mean concentration of 0.25 ± 0.10 mg/kg for bongafish and 0.25 ± 0.19 mg/kg for catfish. The level of contamination was in the order of Zn>Ni>Cd>Co>Pb for catfish and Cd>Zn>Ni>Co>Pb for bongafish [Table 1]. Level of Zn and Ni in both fishes was statistically significant ($P < 0.05$). High levels of cadmium (18.25 ± 7.51 mg/kg) and nickel (7.80 ± 10.06 mg/kg) were recorded in bongafish obtained from Ifiayong (rural) market compared to that observed in catfish where cadmium (15.95 ± 10.15 mg/kg) and zinc (11.80 ± 9.50 mg/kg) were at highest levels. The level of contamination was in the order of Cd>Zn>Ni>Co>Pb for catfish and Cd>Ni>Zn>Co>Pb for bongafish. Pb was the least contamination in both fishes, as shown in Table 2. On the whole, the results revealed that the heavy metal levels were high in fishes from the urban market (Akpanandem market) than the rural market (Ifiayong market) with cadmium and zinc as the most abundant metals in the fishes. There was no statistically significant difference in the levels of heavy metals detected in both catfish and bongafish sold in Ifiayong market.

The mean bacterial and fungal loads of catfish and bongafish in this study from the two markets are presented in Tables 3 and 4. Bongafish from Ifiayong market had the highest fungal load with the mean of $3.18 \times 10^5 \pm 0.084$ cfu/g compared to $1.65 \times 10^5 \pm 0.162$ cfu/g of catfish from the same market. The bacterial and fungal isolates obtained from fish samples in both markets are shown in Tables 5 and 6. A total of 11 bacterial and five fungal isolates were isolated from bongafish, while nine bacterial and six fungal isolates were from catfish sold in Akpanadem urban market. In Ifiayong market, a total of 11 bacterial and eight fungal isolates were isolated from bongafish, while 11 bacterial and six fungal isolates were from catfish. The following culturable microorganisms were isolated from the fishes from both market: *Micrococcus* sp., *Bacillus subtilis*, *Staphylococcus aureus*, *Klebsiella* sp., *Citrobacter* sp., *Salmonella* sp., *Shigella* sp., *Vibrio haemolyticus*, *Staphylococcus albus*, *Escherichia coli, Proteus* sp., and *Serratia* sp., while *Aspergillus fumigatus*, *Aspergillus niger*, *Candida tropicalis,* and *Absidia* sp. were the most predominant fungi.

## DISCUSSION

Heavy metals occur as natural constituents of the earth crust and are persistent environmental contaminants since they cannot be degraded or destroyed. Although these elements are lacking in abundance they are not lacking in significance.[8] In this study, concentrations of five heavy metals were determined in catfish and bongafish sold in Akpanandem (urban) and Ifiayong (rural) markets.

**Table 1:** Concentration of heavy metals (mg/kg) in fishes from Akpanandem market.

| Fish species | Lead (Pb) mg/kg | Zinc (Zn) mg/kg | Cadmium (Cd) mg/kg | Nickel (Ni) mg/kg | Cobalt (Co) mg/kg |
|---|---|---|---|---|---|
| Catfish (*n*=4) | 0.25±0.19 | 15.50±9.99 | 2.55±1.85 | 12.85±9.45 | 0.30±0.12 |
| Bongafish (*n*=4) | 0.25±0.10 | 16.40±12.28 | 19.55±3.84 | 12.45±9.21 | 0.40±0.28 |
| Student's *t*-test | 0.242 | 0.042* | 0.481 | 0.017* | 0.284 |
| WHO limit in fish (ppm) | 0.005 | <0.01 | 0.05 | 0.01 | 0.05 |
| WHO limit in water (mg/kg) | 0.01 | – | 0.003 | 0.02 | 1.00 |

*Significant at $P<0.05$; *n*: Number of replicate analysis

**Table 2:** Concentration of heavy metals (mg/kg) in fishes from Ifiayong market.

| Fish species | Lead (Pb) mg/kg | Zinc (Zn) mg/kg | Cadmium (Cd) mg/kg | Nickel (Ni) mg/kg | Cobalt (Co) mg/kg |
|---|---|---|---|---|---|
| Catfish (*n*=4) | 0.20±0.00 | 11.80±9.50 | 15.95±10.15 | 5.45±7.09 | 0.25±0.10 |
| Bongafish (*n*=4) | 0.15±0.10 | 2.65±4.90 | 18.25±7.51 | 7.80±10.06 | 0.50±0.48 |
| Student's *t*-test | 0.219 | 0.394 | 0.067 | 0.201 | 0.323 |
| WHO limit in fish (ppm) | 0.005 | <0.01 | 0.05 | 0.01 | 0.05 |
| WHO limit in water (mg/kg) | 0.01 | – | 0.003 | 0.02 | 1.00 |

$P>0.05$ (not significant); *n*: Number of replicate analysis

Of the concentrations of heavy metals detected in bongafish obtained from Akpanandem (urban) market, cadmium was the highest followed by zinc and nickel. In contrast, zinc followed by nickel was at high concentrations in catfish from the same market. The concentrations of lead and cobalt in both fishes were low. Fishes sold at Akpanandem market recorded heavy metal contamination in the decreasing order of Cd>Zn>Ni>Co>Pb. The level of cadmium contamination at Ifiayong (rural) market was higher in both bonga and catfishes compared to that obtained at the urban markets. This difference can be attributed to the immediate environment of the fish where these metals could have been taken up by the fishes. This may be due to the fact that all the fishes obtained may have come from the mouth of the Atlantic Ocean or the various estuaries surrounding the state in which the concentration of these metals at different points might have been comparable.[2]

The concentrations of contamination of cadmium and zinc, as seen in this study, exceeded their critical value in the environment as recommended by the WHO.[14] For instance, the WHO pollution threshold of cadmium and zinc is 0.05 and 0.01 ppm, indicating that the results from the sampled fishes with evidence of cadmium and zinc pollution carries attendant health consequences.[14] Although all the fishes studied contained relatively low Pb levels ranging from 0.15 ± 0.10 mg/kg to 0.25 ± 0.19 mg/kg, yet these levels are higher than the WHO recommended a limit of tolerance (0.005 ppm). The findings in this study are comparable to that reported in Minna metropolis, Niger State of Nigeria by Ako and Salihu[15] who reported lower concentrations of

**Table 3:** Bacterial population counts (cfu/g) in fishes by market sources.

| Market | Type of fish (Number of tested) | Mean count (cfu/g) |
|---|---|---|
| Akpanandem | Cat fish (*n*=4) | $1.90\times10^{6}\pm0.071$ |
| | Bonga fish (*n*=4) | $2.30\times10^{6}\pm0.042$ |
| Ifiayong | Cat fish (*n*=4) | $2.18\times10^{6}\pm0.034$ |
| | Bonga fish (*n*=4) | $1.80\times10^{6}\pm0.080$ |

*n*=Number of replicate analysis. Cfu: Colony-forming unit

**Table 4:** Fungal population counts (cfu/g) in fishes by market sources.

| Market | Type of fish (Number of tested) | Mean count (cfu/g) |
|---|---|---|
| Akpanandem | Cat fish (*n*=4) | $1.95\times10^{5}\pm0.257$ |
| | Bonga fish (*n*=4) | $1.75\times10^{5}\pm0.106$ |
| Ifiayong | Cat fish (*n*=4) | $1.65\times10^{5}\pm0.162$ |
| | Bonga fish (*n*=4) | $3.18\times10^{5}\pm0.084$ |

*n*=Number of replicate analysis. Cfu: Colony-forming unit

**Table 5:** Microbial population counts (cfu/g±SD) of fish types from Akpanandem market.

| Microorgnisms | Mean count from Bongafish (cfu/g±SD) | Mean count from catfish (cfu/g±SD) | Student's *t*-test |
|---|---|---|---|
| Bacterial isolates | | | |
| *Micrococcus* sp. | $6.0\times10^{4}\pm0.416$ | $5.6\times10^{4}\pm0.310$ | 0.053 |
| *Bacillus subtilis* | $7.5\times10^{4}\pm0.871$ | $7.3\times10^{4}\pm0.276$ | 0.153 |
| *Proteus* sp. | $5.2\times10^{4}\pm0.816$ | 0 | 0.118 |
| *Streptococcus* sp. | 0 | $6.9\times10^{4}\pm0.863$ | 0.832 |
| *Bacillus cereus* | $5.5\times10^{4}\pm0.771$ | $5.3\times10^{4}\pm0.473$ | 0.069 |
| *Enterococcus* sp. | $6.6\times10^{4}\pm0.564$ | $6.7\times10^{4}\pm0.147$ | 0.864 |
| *Staphylococcus aureus* | $5.2\times10^{4}\pm0.644$ | $4.0\times10^{4}\pm0.715$ | 0.129 |
| *Staphylococcus albus* | $7.1\times10^{4}\pm0.057$ | $4.2\times10^{4}\pm1.050$ | 0.094 |
| *Chromatium* sp. | 0 | $4.9\times10^{4}\pm0.310$ | 0.871 |
| *Actinomycetes* sp. | $7.0\times10^{4}\pm0.665$ | $3.7\times10^{4}\pm0.276$ | 0.782 |
| *Vibrio cholera* | $5.1\times10^{4}\pm0.868$ | 0 | 0.156 |
| *Vibrio haemolyticus* | $6.8\times10^{4}\pm0.658$ | 0 | 0.757 |
| *Shigella* sp. | $7.0\times10^{4}\pm0.873$ | 0 | 0.132 |
| Fungal isolates | | | |
| *Aspergillus fumigatus* | $7.0\times10^{4}\pm0.346$ | $6.5\times10^{4}\pm1.062$ | 0.098 |
| *Aspergillus niger* | $8.3\times10^{4}\pm4.39$ | $8.0\times10^{4}\pm3.025$ | 0.094 |
| *Mucor* sp. | 0 | $8.5\times10^{4}\pm0.475$ | 0.709 |
| *Aspergillus glaucus* | $8.0\times10^{4}\pm0.539$ | $7.0\times10^{4}\pm0.277$ | 0.099 |
| *Candida tropicalis* | $9.2\times10^{4}\pm0.105$ | 0 | 0.797 |
| *Aspergillus flavus* | $6.0\times10^{4}\pm0.768$ | 0 | 0.810 |
| *Aspergillus terreus* | 0 | $1.21\times10^{4}\pm0.868$ | 0.785 |
| *Penicillium* sp. | 0 | $6.25\times10^{4}\pm0.301$ | 0.719 |

Cfu: Colony-forming unit

**Table 6:** Microbial population counts (cfu/g±SD) of fish types from Ifiayong market.

| Microorganisms | Mean count from Bongafish (cfu/g±SD) | Mean count from catfish (cfu/g±SD) | Student's *t*-test |
|---|---|---|---|
| Bacterial isolates | | | |
| *Micrococcus* sp. | $1.70\times10^4\pm0.391$ | $5.40\times10^4\pm0.861$ | 0.100 |
| *Bacillus subtilis* | $2.88\times10^4\pm0.085$ | $1.25\times10^4\pm4.739$ | 0.095 |
| *Proteus* sp. | $1.88\times10^4\pm0.431$ | $1.73\times10^4\pm2.435$ | 0.814 |
| *Streptococcus* sp. | $3.05\times10^4\pm0.613$ | 0 | 0.716 |
| *Bacillus cereus* | $2.40\times10^4\pm0.032$ | $5.25\times10^4\pm0.578$ | 0.099 |
| *Enterococcus* sp. | $1.28\times10^4\pm1.098$ | 0 | 0.094 |
| *Staphylococcus aureus* | $1.51\times10^4\pm0.211$ | $1.25\times10^4\pm0.665$ | 0.111 |
| *Staphylococcus albus* | $1.54\times10^4\pm0.107$ | $2.30\times10^4\pm0.445$ | 0.119 |
| *Chromatium* sp. | $1.08\times10^4\pm0.762$ | 0 | 0.727 |
| *Actinomycetes* sp. | 0 | $1.28\times10^4\pm1.654$ | 0.125 |
| *Vibrio cholerae* | $3.11\times10^4\pm2.301$ | $1.25\times10^4$ 3.186 | 0.815 |
| *Vibrio haemolyticus* | 0 | $2.20\times10^4\pm1.051$ | 0.806 |
| *Salmonella* sp. | $1.68\times10^4\pm1.891$ | $1.28\times10^4\pm0.666$ | 0.805 |
| *Shigella* sp. | 0 | $1.95\times10^4\pm0.874$ | 0.100 |
| Fungal isolates | | | |
| *Aspergillus fumigatus* | $4.70\times10^4\pm0.456$ | $1.97\times10^4\pm0.346$ | 0.144 |
| *Aspergillus niger* | $3.80\times10^4\pm0.681$ | $1.90\times10^4\pm0.478$ | 0.139 |
| *Mucor* sp. | 0 | $2.80\times10^4\pm4.739$ | 0.747 |
| *Aspergillus glaucus* | $4.01\times10^4\pm0.234$ | 0 | 0.823 |
| *Candida tropicalis* | $3.65\times10^4\pm0.478$ | $3.80\times10^4\pm0.861$ | 0.117 |
| *Trichophyton* sp. | 0 | $1.25\times10^4\pm2.434$ | 0.783 |
| *Aspergillus flavus* | $5.32\times10^4\pm0.168$ | 0 | 0.814 |
| *Aspergillus terreus* | 0 | $1.50\times10^4\pm0.186$ | 0.774 |
| *Rhizopus stolonifer* | $2.53\times10^4\pm1.052$ | 0 | 0.838 |
| *Epicoccum* sp. | $4.65\times10^4\pm0.221$ | 0 | 0.818 |
| *Penicillium* sp. | $4.20\times10^4\pm0.754$ | 0 | 0.821 |

Cfu: Colony-forming unit

lead in both smoked and oven-dried fish specimens with mean values ranging from 0.46 to 1.16 mg/kg and 0.54 to 0.76 mg/kg, respectively. Contamination of water bodies by Pb and other heavy metals could be from diverse sources. For instance, these metals can be carried away or blown by the wind from land surface to nearby river used by man for various activities. No matter the source of the metal, the final repositories are usually the aquatic systems. Lead from automobile exhaust systems could be transported in the form of aerosols to surface waters and as atmospheric fallout on land surfaces, which will eventually be washed into the aquatic system by water runoffs. These metals can also be deposited directly on the fish when exposed to the air in the market where they are being sold to consumers.

The fact that there was no statistically significant difference in the concentrations of heavy metals detected in both catfish and bongafish sold in Ifiayong market maybe because the fishes were caught from the same water. In Akpanandem market, the concentrations of zinc and nickel in the two fishes compared to other metals were statistically significant. Akpanandem is an urban market in the city of Uyo, Akwa Ibom State associated with high automobile activities that constantly pollute the environment with some of these heavy metals released from exhaust smoke into the atmosphere. This in addition to inherent metals in the fish from its habitat can contribute to the high levels of the metals observed in these fishes. Daniel *et al.*[2] in Benin City, Nigeria, on the contrary reported a low concentration of heavy metals and high bacterial contamination observed in smoked fish species that was due to improper smoking and unhygienic handling of the products. In view of the low levels of heavy metals reported by the authors, periodic monitoring, and evaluation should be carried out to ascertain the concentrations of heavy metals in the products that can be recommended. The major contamination of heavy metal cases in Nigeria is believed to be associated with lead poisoning. They are most severe in young children because their brains and central nervous systems are still being formed.[16] Similar findings were documented by Abolagba and Iyeru in Benin City Metropolis Nigeria,[17] and by Dike-Ndudim and coresearchers in Owerri, Imo State, Nigeria.[18] Oil exploitation and exploration activities in the Niger Delta region are sources of heavy metal contamination of body water as well as the disposal of metallic waste into the environment.[2]

The results of this study have also revealed that fishes sold in both urban (Akpanandem) and rural (Ifiayong) markets

in Akwa Ibom State are laden with microbial contaminants. Heterotrophic bacteria and fungi as well as other pollutant indicator bacteria such as coliform, fecal coliform, *Salmonella*/*Shigella,* and *Vibrio* organisms were enumerated from these fishes. However, their burden varied with the type of fish and the market. The highest bacterial load enumerated was found in bongafish from Akpanandem (urban) market with a mean count of $2.30 \times 10^6 \pm 0.042$ cfu/g while bongafish from Ifiayong (rural) market recorded the lowest load of $1.80 \times 10^6 \pm 0.080$ cfu/g. This variation can be attributed to gross contamination when transporting the fishes from the sources of supply near the coastal estuaries to the urban market whose distance is farther than Ifiayong rural market. However, higher fungal count of $3.18 \times 10^5 \pm 0.084$ cfu/g found in bongafish from Ifiayong (rural) market may be due to poor handling and storage in the rural area that led to the formation of spores by fungi usually at unfavorable conditions which permit growth of spores into vegetative cells when environmental conditions become favorable. Results obtained in this study are comparable to that reported by Akinwumi and Adegbehingbe[7] that revealed a fungal load of $3.0 \times 10^3$ cfu/g in dried fish sold in a market in Ondo State.

In addition to the above findings, Kang and Frank[19] reported lower bacterial count ranging from 1.80 to $3.60 \times 10^2$ cfu/g in fishes in the Niger Delta Region of Nigeria. Several factors could have contributed to the contamination of the fishes such as environmental pollution from human activities such as construction works as well as indiscriminate disposal of organic wastes, including fecal matter. These are probably responsible for the presence of microbial contaminants in the fishes.[20] The high heterotrophic bacterial densities in fishes from the urban market may be attributed to intense human activities and consequent contamination from dust since higher concentrations of bacteria are usually present and are released from soil when the dust is raised.[21] Another significant source of microbial contamination in the fishes is the human factor where humans themselves act as carriers of saprophytic and pathogenic microflora that are known to cause illness in susceptible persons.[22] This could also be the reason for higher densities of coliforms, fecal coliforms, and fungi recorded in this study, some of which are pathogenic.

*Salmonella*, *Shigella*, *S. aureus*, *Streptococcus* sp., *Bacillus* sp., *E. coli,* and *Enterococci* are among the known pathogenic organisms isolated from fishes in this study. Ibrahim *et al*.[23] evaluated the occurrence and antimicrobial susceptibility profiles of *Salmonella* serovars from fish in Maiduguri, Nigeria and concluded that *Salmonella* sp. is among the pathogens associated with fish contamination in the region and constitute serious health risks for the human population.[23] The most common fungal isolates in this study were those from the genera *Aspergillus* which are broadly present in nature, including soil, cereal grains, hay, and other plant material or foodstuff.[24] Exposure to these molds has been associated with a variety of adverse health outcomes including gastrointestinal, respiratory, hematological, immunological, and neurological system disorders and/or diseases.[25] Some *Aspergillus* species are reported to cause liver diseases due to aflatoxin produced by these microorganisms.[24]

There is a well-established fact that contaminated food is a major source of transmission for pathogenic bacteria. It is a major cause of enteric diseases in developing countries and is a major cause of mortality and morbidity.[26] Seafoods as a main source of foodborne infections have a great impact on food safety. In this study, pathogenic organisms have been enumerated from fishes sold in Ifiayong (rural) and Akpanandem (urban) markets in Akwa Ibom State with varying microbial load in the studied fishes.

## CONCLUSION

This research finding revealed that the fishes sold in these markets were heavily contaminated with heavy metals (cadmium, nickel, lead, and zinc) and pathogenic bacteria (*S. aureus*, *Streptococcus* sp., *Bacillus* sp., *E. coli*, *Salmonella*, *Shigella,* and *Enterococci*) as well as pathogenic fungi such as *Aspergillus* sp. There is a potential risk of eating contaminated smoked fishes, improperly cooked or processed fish especially the species studied that are sold at Akpanandem and Ifiayong markets in Akwa Ibom State and beyond. These fishes are equally transported to other parts of Nigeria from the same fishing source in Akwa Ibom State. Therefore, conscious efforts should be made toward the reduction of heavy metal contamination of environments such as the frequent cases of oil spills and air pollution from oil exploration activities in the Niger Delta region. Adequate waste disposal system should be put in place to avoid incessant waste disposal in the environment, especially water bodies where aquatic lives may be contaminated.

### Declaration of patient consent

Patient's consent not required as patients identity is not disclosed or compromised.

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Nil.

### Conflicts of interest

There are no conflicts of interest.

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